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Improvement in muscular strength, body flexibility and balance by yogasana and with reduced detraining effects by yoga breathing maneuvers: A non-randomized controlled study

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ABSTRACT

Background: *Yoga* was reported to have the potential to improve physical fitness. Its applications are being used by common persons for wellness, but literature on the training and detraining effects of components of *yoga* is scarce.

Objectives: To explore the potential of different proportions of *yoga* postures (*Yogasana*) and *yoga* breathing maneuvers (YBM), consisting of *Pranayama* and *kriya,* on muscular strength, flexibility, and balance in training and detraining management.

Methods: : 32 physically active male students, aged 20.5 ± 1.3 yrs, were divided into control (CG) and *yoga* group (YG). YG practiced *yogasana*, YBM, and dhyana for 45 min in each session for 6 days per week for 12 weeks. From 1st week to 6th week, they practiced *yogasana* in greater proportion. 7th week onwards YBM was inducted by increasing its duration and varieties. CG did not practice *yoga*. Back-leg strength (BLS), Hand Grip Strength (HGS), flexibility, and balance were recorded before, the 6th week and 12th weekend of training.

Results: :.In YG, the pre-training value of BLS was 110.8 ± 12.6 kg. It increased (2.3 %) to 113.3 ± 11.4 kg ($p < 0.001$) on the 6th weekend. On the 12th weekend, it further increased in lesser magnitude (0.4 %) to 113.7 ± 11 kg ($p < 0.05$) and the pattern of improvement was the same in other parameters, but in flexibility and balance its magnitude was greater ($p < 0.001$). CG did not show such changes.

Conclusions: : *Yogasana* helps in the improvement of muscular strength, flexibility, and balance and YBM counteracts detraining effects in the absence of *yogasana*. Judiciously selected components of *yoga*/YBM may have applications in sports, occpational health and recuperative patients.

1. Introduction

The ancient system of *Hata yoga* evolved with its various forms through millennia by experiences of *yoga* masters. Grossly it has three major components i.e. *Yoga* physical postures, which are mostly static called *yogasana, yoga* breathing manuevers (YBM) called *Pranayama* and *Kriya* in *yoga* parlance and *dhyana*. All of these components individually and also collectively influence various systems of the body bringing about positive effects on both the physical and mental functions of an individual [1–3]. Their beneficial effects are being used as a therapy to cure diseases [4,5], improve physical performance [6,7] muscular strength and endurance [1,8,9] body flexibility [10–12], balance [12, 13], reaction time [14] and aerobic capacity [7]. In general, different studies showed that the improvement in muscular strength by yogic practices varies in magnitude according to age, training duration, and intensity along with the general lifestyle and health of an individual [11, 15–17]. The same applies to other fitness-related parameters. Again, different *yoga* protocols with various combinations of *yogasanas*, YBM and *dhyana* may also have varied outcomes on aerobic capacity, muscular strength and endurance, body flexibility and balance. This is because various components of *yoga* may have different effects on those parameters. This was observed in *Bikram yoga* in which handgrip strength (HGS) did not change but body flexibility improved in young volunteers [18]. In another study [19], upper body and trunk dynamic

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muscular strength and endurance, body flexibility and health perception improved among *Astanga yoga* practitioners who practiced *yogasana,* YBM and *dhyana* for six weeks; but exclusively *yogasana* practice showed improvement only in muscular strength, endurance and flexibility without having any effect on health perception. Many of these variations may also be due to the detraining effects when some of the components of *yoga* practices were not done in the required duration and intensity.

As such, systematic studies on the detraining effects in *yoga* practices are sparse, although different *yoga* programs are being incorporated with various proportions of duration and the number of *yogasanas*, YBM and *dhyana*. Sometimes, based on the specific needs of the *yoga* practitioners and shortage of time, specific components are not included for sufficient time. This may result in detraining effects in different performance-related parameters. In sports and athletic training, studies on detraining were done. An eight-weeks strength training program followed by an eight-weeks detraining period was reported to decrease muscular strength after the detraining period [20]. Likewise, it was reported [21] that explosive strength was reduced by detraining in adolescent male basketball players. Even partial withdrawal of a specific type of physical training component showed detraining effects leading to performance deterioration [22]. So far only one paper i.e. D'souza and Avadhany [23] reported that among pre-pubertal (7–9 years) children, calf muscle endurance increased after 3 months of *Suryanamaskara* practice but it reduced after 3 months of detraining period.

In this background, the primary objective of this study was to observe the effects of *yoga* training with *yogasanas* and YBM in different proportions on muscular strength, body flexibility, and balance. A secondary objective was to observe the effect of detraining due to lesser practice of either *yogasanas* or YBM under similar conditions. Findings would help in the fitness training program to improve these physical fitness components. Again, it will also help in the management of detraining/deconditioning effects by the use of different components of *yoga* in the right proportions to maintain the physical fitness achieved during training.

2. Material and methods

2.1. Participants

A total of 32 healthy male undergraduate student volunteers from Ramakrishna Mission Vivekananda Educational and Research Institute, Belur Math, Howrah participated in this study. All participants had rural background. They were residing in the same hostel and had the same standard diet as used to be supplied from a common mess. All of them had a uniform pattern of daily routine and activity. Table-1 shows the physical characteristics of the participants.

Sample size: The sample size was calculated according to the standard formula and method of Cochran [24]. The standard deviation (s) and margin of error (d) of basic variables at a 5% level of confidence ($p < 0.05$) were considered. A trial run by recording all the parameters by using the same equipment and measurement procedure as would be done during the actual experiment, in the authors' laboratory, was conducted on the same category of participants who would take part in this study. The highest sample size calculated from all the basic variables studied was selected. This was 38 considering 2 groups to be formed i.e. YG and CG. As given in Fig. 1, the same number of participants were not available following the exclusion/inclusion criteria. Thus, ultimately sample size of 32 was selected and participants were divided into two homogeneous groups.

Sampling: Participants were selected by purposive sampling keeping an eye to get homogeneous samples following inclusion and exclusion criteria. Later, group selection was made by coin tossing method. Although group selection was done randomly, this randomisation has not been highlighted in the text, as same could not be done at the individual participant level also.

Table 1
Physical characteristics of the participants (Mean ± SD).

Yoga Group (YG)				
Training	Age(yrs.)	Height(cm)	Body weight(kg)	Body fat (%)
Baseline	20.3 ± 1.3	167.5 ± 5.3	55.2 ± 6.1	13.3 ± 2.3
6th week			56.3 ± 5.1	13.2 ± 2.3
12th week			56.7 ± 5.1	13.2 ± 2.1
Control Group (CG)				
Training	**Age (yrs.)**	**Height(cm)**	**Body weight(kg)**	**Body fat (%)**
Baseline	20.8 ± 1.4	166.9 ± 5.1	55.4 ± 4.92	13.14 ± 2.4
6th week			56.06 ± 5.09	13.42 ± 2.1
12th week			56.31 ± 4.98	13.51 ± 1.8

2.2. Inclusion criteria

Participants had to be in the age range from 18 to 21 years. All of them had to be medically fit as could be checked by interview and medical records. They should have uniform activity patterns and lifestyles. Participants should have food intake from a common mess of the institute.

2.3. Exclusion criteria

Participants having the habit of smoking, taking alcohol, or any intoxicating agents were excluded from this study. Those with athletic backgrounds, already a *yoga* performer were not included in the study. Individuals having any cardiovascular, respiratory, or other disorders, injuries, and locomotor problems, which may affect their performance were not included in the study.

2.4. Experimental procedure

The study was conducted from July to September 2019. Participants were explained the purpose of the study in their mother tongue about *yoga* training and exercise tests to be conducted and the risk factors involved. Their informed consent was obtained before the study. The experiments and training involved were conducted following the standard international norms/guidance for conducting experiments on human participants and as per 'Revised National Ethical Guidelines for Biomedical and Health Research involving human subjects', ICMR,2017, New Delhi [25]. Approval of the institutional ethical committee (Assigned no: RKMVERI/IEC-20/SSY-6) of the university, Ramakrishna Mission Vivekananda Educational Research Institute was obtained. All were instructed not to practice any other form of high-intensity competitive athletics or games except 30–40 min of recreational games (as they used to do before this study) in the afternoon during the 3 months of this study.

Participants were divided into two groups i.e. Yoga and Control group with 16 participants in each group. Hereafter, Yoga and control groups will be referred to as YG and CG respectively.

2.5. Design of experiment and yoga training

YG practiced *yoga* in the morning under the supervision of two qualified yoga instructors. The timeline for *yoga* practice sessions during the 12 weeks of training is given in Table 2.

They practiced *yoga* in a session of 45 min including 5 min of freehand loosening exercises in the beginning before yoga practice each day for 6 days in a week for 3 months. The main *yoga* training components were yoga*sanas* (*physical posture)* and YBM (*Pranayama* and *Kriya),* which were practiced for 30 min according to the standard procedure [26]. O*m* chanting and meditation (*Dhyana*) were performed at the end of each session for 5 min. yoga*sanas* as they practiced were: *Makarasana, Sukhasana, Shavasana* (Yoga relaxative postures*)* *Trikonasana, Tadasana, Sarala Bhujanasana, Katiichakrasana, Sahaja*

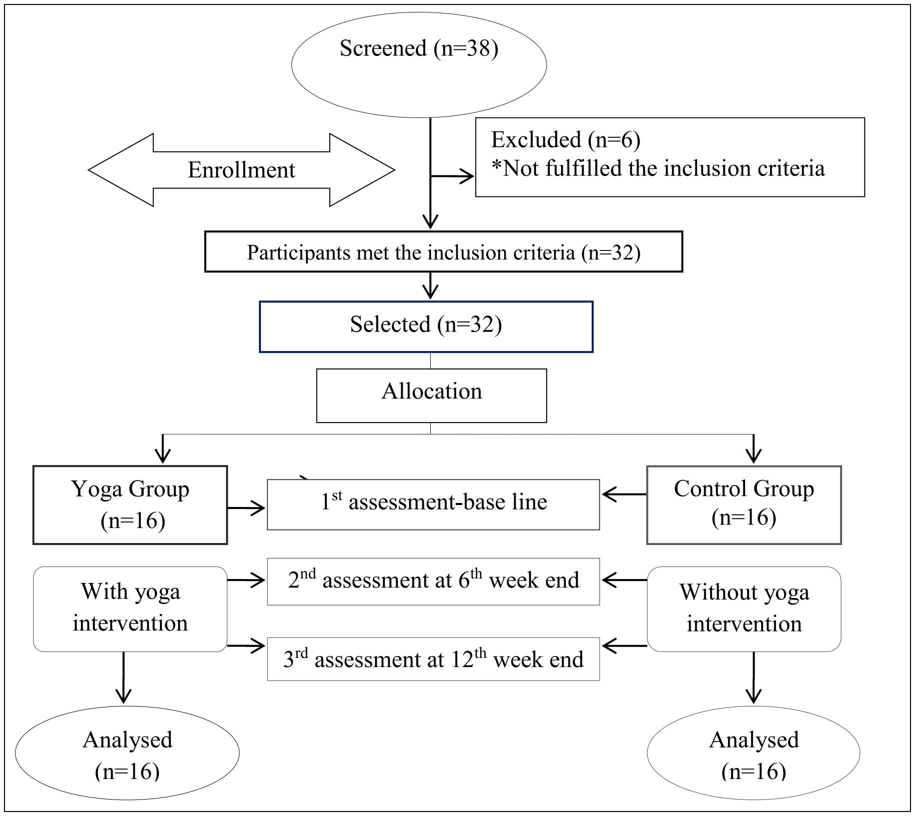

Fig. 1. Flow chart for recruitment, selection and group assessment of subjects.

Table 2

Time Line of Yoga Training programme. Only 30 minutes of yoga practice has been shown with the duration of *asanas* and YBM practice in a session for 6 days in a week. Total training includes loosening exercises and *Om* chanting along with meditation respectively for 5 minutes each in the beginning and end of a Yoga session

1st week	2nd week	3rd week	4th week	5th week	6th week
YBM (5 min) Asanas (25 min)	YBM (5 min) Asanas (25 min)	YBM (6 min) Asanas (24 min)	YBM (7-8 min) Asanas (22-23 min)	YBM (9-12 min) Asanas (18 -21 min)	YBM (9-12 min) Asanas (18 -21 min)
7th week	**8th week**	**9th week**	**10th week**	**11th week**	**11th week**
YBM (17-20 min) Asanas (10-13 min)	YBM (18-20 min) Asanas (10-12 min)	YBM (18-20 min) Asanas (10-12 min)	YBM (18-20 min) Asanas (10 -12 min)	YBM (30 min)	YBM (30 min)

dhanurasana, Ardhasalabasana, Pashchimottanasana, Janushirasana, Ardha matsyendrasana and *Shalabhasana.* YBM components included *Kapalabhati (*a *Kriya* in *Hatha* yogic parlance*)* and *pranayama i.e. Anuloma viloma, Bhasrika, Ujjai* (Ujjai) and *Bhramari*. The duration of *yogasana* practice was reduced gradually throughout the training period to reveal the detraining effects if any on various parameters due to lesser practice of *yogasanas*. According to the rules of *yoga* practice, YBM should be introduced very slowly in a *yoga* program. So, only two YBM were introduced in the 1st and 2nd weeks. From the 3rdweek duration of those YBM practices increased along with one more new YBM. Thereafter, it was introduced each week up to 6th week as per the ability of the participants, along with the reduced practice time for *yogasanas*. Up to 6th week, they devoted a maximum of 17 min for YBM (including rest pauses in relaxative postures like *Sukhasana or Shavasana*) and a minimum of 18 min for yoga*sanas* which also included various relaxative yoga*sanas* like *Sābhāsāna*, *Mākarāsāna* and *Sukhāsan.* The duration of yoga*sana* practice gradually reduced from the 7th week onwards to the 10th week, when maximum duration of YBM practice was for 20 min, while minimum duration of yoga*sana* practice was only 15 min including relaxative yoga*sanas*. Last 2 weeks (i.e.11th and the 12th week) they practiced only YBM with relaxative yoga*sanas,* while maintaining the duration of the practice of loosening exercises and Om chanting period the same. CG did not practice yoga. In the afternoon, both YG and CG participated in recreational games for 30–40 min. Exercise intensity as measured by heart rate monitor during the games was in a similar range for both groups. In Fig. 1 in a flow chart, the step-by-step study protocol has been given.

2.6. *Data collection*

Participants' basic data on height (cm) was measured by a stadiometer and body weight (kg) and fat (%) were measured by a body composition analyser (ioi353, Poland).

The whole experiment was performed in a room temperature varying from 25 to 28 °C. Recordings of Back-leg Strength (BLS) and Handgrip Strength (HGS) from both the right and left hand in kg, body flexibility (cm), and balance (Sec) were taken on both YG and CG at baseline before the commencement of training, at the end of the 6th week and 12th week of training. All of these measurements were taken following standard methods [27].

2.6.1. *Back leg strength (BLS)*

It was measured by a Back leg strength dynamometer (Baseline, USA). During the measurement, the participant stood in 30° lumbar flexion. Then, he pulled the handle of the dynamometer as much as possible without bending the knees while the recording was being taken. Every volunteer performed three trials with a rest of 1 min between each trial and the best reading was noted.

2.6.2. Hand grip strength (HGS)

It was measured by a handgrip dynamometer (Baseline, USA) and was taken from both the right and left hand. During its measurement participant stood with the elbow fully extended and kept both hands by the side of the body. Then, they applied maximal grip force while holding firmly the dynamometer with one hand. The dynamometer displayed the peak force. Every volunteer performed three trials with a rest period of 1 min between each trial in each hand and the best reading was noted.

2.6.3. Body flexibility

It was measured by the sit and reach test. A 'sit and reach test box' was used. For measurement, the participant sat on the floor with the legs extended, both knees locked and the soles of the feet were placed against the 'sit and reach test box' with one hand on top of the other. Then, he slowly reached toward the toes. The individual tried to reach maximum distance and held the position for at least one to 2 s while distance (cm) was recorded. No jerky movement was allowed. The best reading in centimeters was recorded from three trials.

2.6.4. Balance

It was measured by the 'Stork stand test'. During this test participant was instructed to stand on the non-slippery floor and to place the hands on the hips after removing the shoes. Then he stood on one leg, placing the non-supporting foot against the inside knee of the supporting leg. A stopwatch was started when the participant raised the heel from the floor. The participant maintained balance on the ball of the foot. The stopwatch was stopped, if any of the things happened as follows: If the supporting foot deviated in any direction, the hand (s) came off the hips, the non-supporting foot lost contact with the knee, and the heel of the supporting foot touched the floor.

2.7. Statistical analysis

Comparisons among groups and training duration: The distribution of data was checked for normality by the Shapiro-Wilk test. Parametric statistics were used because all data were normally distributed. Repeated measures parametric data was checked for sphericity using Mauchly's test and if violated, the Greenhouse-Geisser correction was used. Two-way analysis of variance (ANOVA) with repeated measure (group vs. time) followed by the Bonferroni post hoc test was used to analyse the significant differences in BLS, left and right HGS, flexibility and balance between YG and CG, and between measurements in consecutive training phases. The significance level was set at $p < 0.05$. All data were analysed with SPSS v.210 (SPSS Inc, Chicago, Illinois, USA).

3. Results

In YG, the pre-training baseline mean value of BLS was 110.8 ± 12.6 kg. After 6 weeks of *yōga* training with more yoga*sana* practice, it increased significantly to 113.3 ± 11.4 kg ($P < 0.001$). On the 12th weekend, it slightly increased to 113.7 ± 11 kg with a comparatively lower level of significance ($p < 0.05$) as compared to the 6th-week end. The magnitude of improvement from baseline to 6th-week end was 2.3 %, while it was only 0.4 % in the case of 6th week to 12th-week end. In CG, the baseline value of BLS was 112.3 ± 11.4 kg, which did not change significantly on the 6th and 12th weekend (Fig. 2A). An almost similar pattern of changes due to *yoga* practice was found in YG in both Right and Left HGS (Fig. 2B and C).

As is given in Fig. 3, body flexibility (Fig. 3B) and balance (Fig. 3A) improved with a very high level of statistical significance ($P < 0.001$) at the 6th-week end in the 1st half of the training period.

In comparison between the 6th and 12th weekend, BLS improved with a higher level of significance ($P < 0.01$) in difference but both right and left HGS showed the same trend without statistical significance. In flexibility and balance, the differences between respective mean values between the 6th week and the 12th-week end were highly significant ($P < 0.001$). This showed that during the second half of the *yoga* training, except in HGS, the improvement in all the parameters was highly statistically significant, in which balance and flexibility prominently improved at a very higher level of significance.

In inter-group differences, only body flexibility showed significantly ($p < 0.01$) higher values in YG than that of CG on the 12th weekend (Fig. 3B).

The magnitude of improvement from baseline to 6th weekend in BLS, Right HGS, Left HGS, flexibility, and balance were 2.3 %, 3.6 %,3.3 %,31.6 %, and 13.6 % respectively, but between the 6th weekend to 12th-weekend, same were comparatively in lower magnitude i.e.0.4 %, 0.9 %, 01.2 %,5.3 %, and 2.7 % respectively. CG did not show any significance of difference among the mean values in all the parameters.

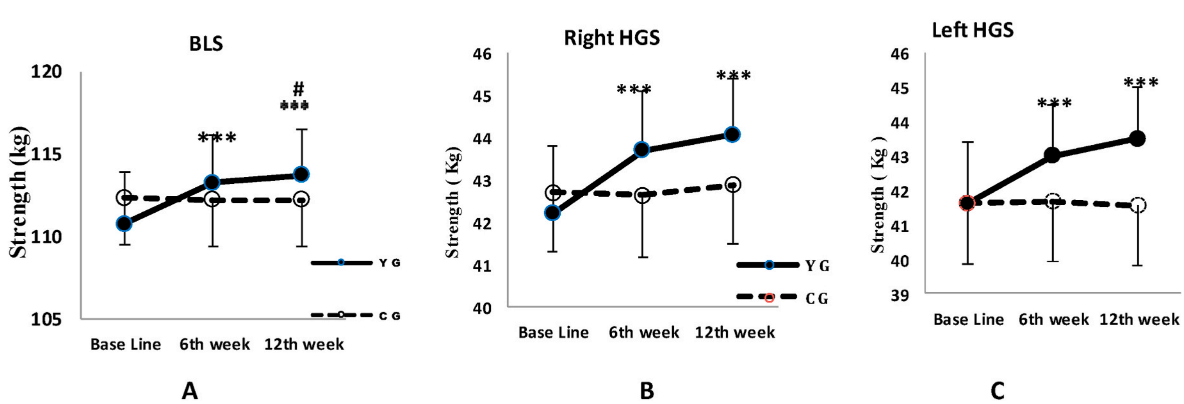

Fig. 2. Fig:2A, 2B, and 2C show changes in the value of BLS, Right HGS, and Left HGS of YG & CG respectively at baseline, at the 6th week, and 12th week end of training. Open circles with dotted lines and filled circles with continuous lines represent mean ± SEM for CG (n = 16) and YG (n = 16) respectively. Compared to the baseline, YG shows highly significant ($p < 0.001$) improvement in all parameters on the 6th and 12th weekend. Again, compared to the 6th week, all show improvement at the 12th weekend, but its magnitude is comparatively lower. BLS shows a significantly higher ($p < 0.05$) value on the 12th weekend compared to the 6th weekend. CG has not shown such improvements. * denotes the significance of the difference from baseline to 6th week and 12th week. # denotes significant difference between 6th week and 12th week. *** denotes $p < 0.001$, # denotes $p < 0.05$ and ##denotes $p < 0.01$.

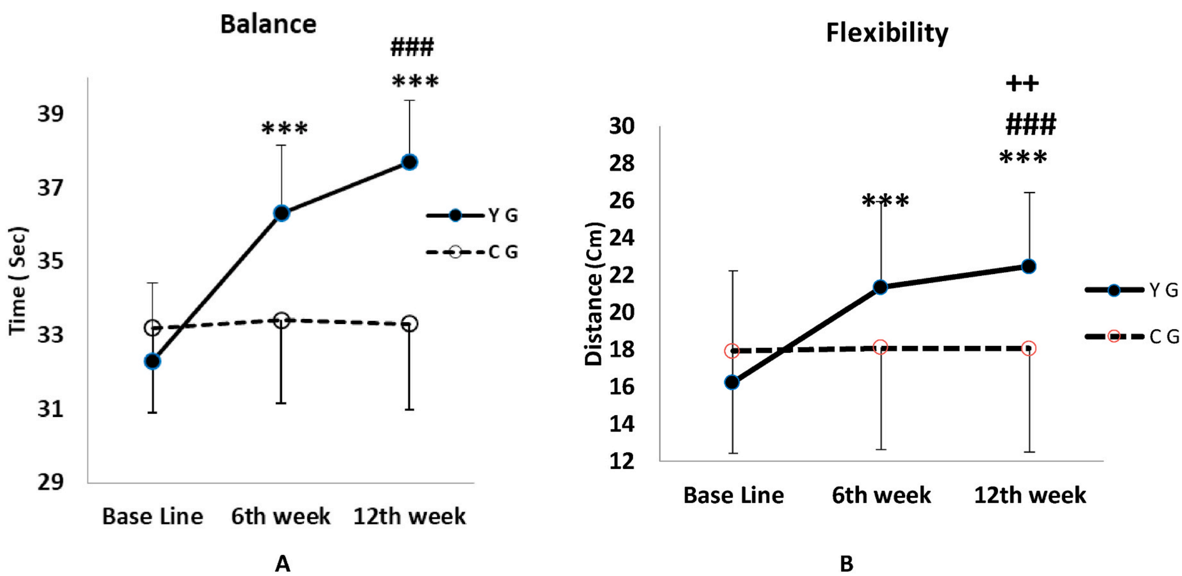

Fig. 3. Fig. 3A and B shows changes in Balance and Flexibility of YG and CG respectively at baseline, at the 6th week and 12th weekend of training. Open circles with dotted lines and filled circles with continuous lines represent mean ± SEM for CG ($n = 16$) and YG ($n = 16$) respectively. Compared to the baseline, YG shows highly significant improvement on the 6th and 12th weekend in both parameters. But, as compared to the 6th weekend at the 12th weekend, though the improvement in both parameters is very high in significance, the magnitude of change in mean values is comparatively lower, showing a detraining effect, which might have been counteracted by YBM. CG shows no such changes. In inter-group differences, only body flexibility has shown significantly higher values in YG than that of CG on the 12th weekend. *denotes the significance of the difference from baseline to 6th week and 12th week. # denotes significant difference between 6th week vs 12th week. + denotes a significant difference between YG and CG. *** denotes $P < 0.001$, ## denotes $p < 0.01$, ++ denotes $P < 0.01$.

4. Discussion

In the present study muscular strength, flexibility, and balance have improved throughout *yoga* training. This happened mostly due to *yogasana* practice, as the magnitude of improvement reduced with the gradual withdrawal of *yogasana* and greater incorporation of YBM in the 2nd half of 12 weeks of *yōga* training (Figs 2 and 3). Thus, the effects of *yogasanas* have reduced along with the withdrawal of its practice within 5–6 weeks of training, even if it is partial. Performance reduction has been reported after partial withdrawal of training in conventional physical training [22]. This study also indicates that compared to muscular strength, the improvement takes place in greater magnitude in body flexibility (31.6 %) and balance (13.6 %) by *yoga*. In general, yoga may help in the improvement of all the parameters in a physical training program.

On the 12th weekend, the expected greater magnitude of improvement did not happen due to greater detraining effects as a result of the lesser *yogasana* practice. Again, the expected magnitude of the detraining effect due to lesser *yogasanas* practice has also not occurred. This may be the result of the greater amount of YBM practice, as from the 7th week up to the 12th week the YBM practice was in greater proportion i.e. up to 50 % of the total time of *yoga* practice. Thus, it is revealed that YBM may have a possible role in counteracting the detraining effects of muscular strength, flexibility, and balance, which may have potential applications in physical training. Earlier reports indicating the possible role of YBM in the improvement of $\dot{V}O_{2max}$ through cardiorespiratory conditioning [7,28] and those of others [5], indicating better oxygenation along with the improvement of cardiovascular function, have relevance to it. This is because YBM does this in addition to its role in counteracting the detraining effect of strength, flexibility, and balance as has been observed in this study. This can be attributed to the effect of YBM on the brain [29,30] and also other psychophysiological effects in general [14,31,32]. In parallel studies, under the same project with the same *yoga* protocol, improvement in both auditory and visual reaction time and also in predicted $\dot{V}O_{2max}$ have been observed at the mid-phase of *yōga* training and it further improved in a greater magnitude, when participants practiced YBM more in the second half of 3 months of training. This indicates its application in both physical/sports training and detraining.

4.1. *Novelty of the study*

The specificity of this study is that it includes different components of *yoga* in various proportions under the single *yoga* training protocol, on the same participants, at different points of time, which helped to find out the effect of *yogasanas* and YBM separately as well as their interactions while avoiding intergroup variations. Thus, the potential role of *yoga* with its different components in both physical and sports training has been revealed. To the best of our knowledge, no study has been conducted so far with this type of approach with a similar aim, while making a *yoga* protocol, keeping in mind its utility in physical/*yyoga* training. This is also true and very important for the management of the detraining effect by YBM during periodization in sports, in occupational health and among patients in the recuperative stage, which has not got its due place with scientific attention. Further discussions concerning individual parameters are as follows.

4.2. *Muscular strength*

Since yoga*sanas* are mainly an isometric type of exercise, it help in the improvement of muscular strength as it is found in any resistive exercise. *yogasana* training among the participants in this study has helped to improve muscular strength by better neural drive from the brain involving both the mechanisms of recruitment and rate coding of muscle contraction to achieve greater force which resulted in greater muscular strength.

4.2.1. *Left and right HGS*

Muscle groups related to HGS are mostly involved in *Sahaja dhanurasana, Ardha matsyendrasana, Bhujangas* and *Tadasana* [33]. So its improvement may be related to the greater practice of those yoga*sanas*. Proportionately more *yogasana* practice for 1st 6 weeks of training has shown significant improvement in HGS. This trend has been maintained, though at a lower magnitude, during subsequent 6 weeks, even when gradually more YBM has been practiced by participants instead of *yogasanas,* indicating the maintenance of strength by YBM practice, which also has counteracted the detraining effect.

The results of our study are consistent with earlier studies [3,34], which have reported significant improvement in muscular strength and endurance by *Hatha yoga* training. Ray et al. [8] have reported that *yoga* exercises help in significant improvement in endurance time while pulling a handspring, indicating reduced fatigue. This had been supported by the evidence of decreased biceps and triceps muscles' EMG amplitude, indicating better recruitment of muscle fibers among *yoga* practitioners. Significant improvement in HGS endurance, without change in HGS, is not a very uncommon outcome of *yogasanas* practice [34].

Most of the volunteers in this study are right-hand dominant. Only two volunteers are left-hand dominant. Although HGS improvement has happened in both hands, the magnitude of its improvement is greater in the respective dominant hand by training. This is perhaps due to the fact that participants could exert more force in the dominant hand.

4.2.2. Back leg strength

The muscle groups related to it get involved mostly in 8 *yogasanas* i.e. *Ardhashalabhasana, Janushiirasana, Ardha matsyendrasana, Trikonasana Shalabhasana, Tadasana, Sahaja dhanurasana* [33] as participants practiced. So its improvement may be attributed to these *yogasanas*. During the first 6 weeks of training, due to greater *yogasanas* practice, it has improved remarkably like HGS. This trend has been maintained at the 12th weekend even after greater YBM practice instead of *yogasanas*. In the 2nd half of training, its improvement has been at a greater level of significance than that of HGS. Similar differences among these two parameters have been reported by D'souza and Avadhany [23], attributing it to greater involvement of leg muscles in standing *yogasana* postures.

4.3. Mechanisms of increased muscular strength

The basic aspects of any physical training i.e. improvement in the capillary-to-fiber ratio and alteration of mitochondrial density, to maintain better blood circulation for a better supply of oxygen and nutrients to the tissues may happen in *yogasanas* practice. The YBM strengthens the respiratory muscles for better breathing and also in economy of breathing, which in turn helps for better oxygen supply to different tissues in the body, particularly the very active ones, leading to better performance [28]. Apart from this, the role of neuro-regulatory mechanisms through better activity of sensory and motor function may have a great role.

In this context, it is of considerable interest to mention the study of Raghuraj et al. [35], who found that *yoga* breathing through a particular nostril or alternative nostrils has positive effects on the HGS. Relevantly, another study [36] has shown no significant improvement in HGS by selecting *yoga* breathing exercises on a limited number of participants. The difference between the earlier study [35] and the later one [36] is in sample size, as the earlier study had been done on a larger sample size. So, it depends on intensity, duration, and types of YBM as well as the number of participants and on inter-individual variations. The improvement in muscular strength by YBM can be supported by the observation [30], that the latency (faster neural processing) and amplitude (greater neural recruitment) of mid-latency auditory evoked potential (AEP-MLR) improve after YBM practice. A similar trend is being shown in visual evoked potential as well as in both sensory and motor nerve conduction [37]. All of these indicate that *yoga* as such and YBM and meditation in particular, have effects on related structures of the brain by better synaptic activity with the help of its capacity to promote neuroplasticity. It is relevant in this context, that the brain-derived neural factor (BDNF) which facilitates in reorganization of neural activity is positively correlated with muscle strength [38] and its secretion is also improved by yogic practices in general and by meditation. HGS improvement is related to better cognitive functions like processing speed and sustained attention [39] and this is also improved by *yoga* [2,30]. This indicates the possibility of a relationship between improvement in attention and greater muscular strength improvement in this study by greater YBM practice in the 2nd half of *yoga* training. An earlier study [29] indicates that diaphragmatic breathing helps in sustained attention improvement along with reduced cortisol levels (better stress management) among healthy participants. YBM has also a similar breathing pattern, which might have improved attention. So, improved attention and faster neural processing may also be factors to improve muscular strength.

4.4. Body flexibility

The improvement of body flexibility can be attributed to repetitive stretching through the practice of *yogasanas* and increasing blood circulation to muscles and connective tissue. During *yogasana* practice in the final position, the specific yoga posture is maintained for a period of >20 s. Controlled breathing is recognized as one of the most important elements to get a better response in the muscle. In this study, participants have practiced *Janu Shirsasan,* which may help to improve the strength of spinal muscles along with hip flexors and hamstrings. Another yoga*sana* i.e. T*rikonasana* acts on the muscles of the chest, hips, and hamstrings and thus may have a role in body flexibility. A significant increase in flexibility after yoga interventions with different types of yoga protocol, age groups, and genders has been reported earlier [2,3,34]. Greater neuromuscular coordination as a result of greater YBM practice might influence flexibility, which has improved in a highly significant fashion at the 12th-week end as compared to the 6th week (Fig. 3B), which has not even been seen in this magnitude in other parameters like muscular strength (Fig. 2), except in balance (Fig. 3A).

4.5. Balance

The sensorimotor control systems for maintaining balance in human depends on the sensory inputs received by the brain from sensory organs i.e. from eyes, vestibular organs in the inner ear, muscles, and joints. The integrated results of various sensory inputs get transmitted through the brain stem by nerve impulses to the muscles of the various regions of the body, which control the movements of the eyes, head, neck, trunk, and legs. Thus, an individual can efficiently maintain balance. It has been reported [12] that body balance improves among male college athletes by biweekly yoga practice for 10 weeks. In a study [40] on the effect of yoga on balance and mobility among older people, it has been found that yoga practitioners could have a significant improvement in balance, gait, and mobility. The improvement in muscular strength and flexibility, as described above, might have both direct and indirect influence on improving balance. The improvement in balance by YBM due to its effect on the function of the brain may be related to the positive effect of diaphragmatic breathing on the brain [29,30], indicating better sensory neural processing in mid-latency response of auditory evoked potential, a reflection of better neural recruitment and function at the mesencephalic region. Improved muscle strength and endurance by yoga practice [1,8] may be responsible for this, which happens due to delayed fatigue as it takes place in antigravity muscles as a result of alternating recruitment of different groups of motor units during muscle contraction. This also indicates possible well-coordinated reciprocal action of synergic and antagonistic muscles which has been brought about through the practice of yoga*sanas* with its slow and steady movement to achieve final static postures. With this, the contribution of YBM as discussed above may also have been there, as at the 12th weekend a very highly significant improvement compared to the 6th weekend has been observed in balance (Fig. 3A), which has not been found in other parameters except in body flexibility (Fig. 3B).

4.6. YBM counteracting detraining effects of muscular strength, flexibility, and balance

Training and detraining effects depend on the basic rule of physical training, which follows well known FITT formula (Frequency, Intensity, Types, and Time). In our study after the 6th week of training, there is a change in the training type i.e. duration of *yogasana* practice for a total session of 45 min, gradually reduced to accommodate the duration of more YBM practice. Therefore, both the frequency and intensity of *yogasana* practice also got reduced to a greater extent. Due to this, there is a reduction in the magnitude of improvement of muscular strength, body flexibility, and balance components at the 12th-week end of yoga training. It has been reported [18] that 8 weeks of *Bikram* yoga training could not significantly change HGS due to insufficient training stimulus for neural and muscular adaptation. In different sports populations, detraining effects of muscular strength, flexibility, and balance are generally seen after 6–8 weeks. Faigenbaum et al. [20] have observed that 8 weeks of strength training followed by detraining for 8 weeks caused a significant decline in muscular strength. The periodization of sports training has three phases i.e. preparatory phase (with a focus mainly on physical preparation), the competitive phase (mainly emphasis on competition), and the transition phase (stressing mainly on relaxation and maintenance of general physical fitness). The duration of the transition phase has been recommended mainly for 3–4 weeks without lingering up to 5 weeks. They have also indicated that in case of longer than 5 weeks of detraining the physical performance declines. In our study, the detraining in various parameters in the absence of *yogasana* practice happened in the 2nd half of the training period, when it happened partially from the 7th to 9th week of yoga practice and later completely for the last 3 weeks. This detraining effect has not been reflected fully in all parameters as expected, possibly due to the greater duration of YBM practice. Although YBM has no direct effects on the activity of the different muscles as in *yogasanas* its effect on the brain and peripheral nervous system also needs to be considered. The psycho-physiological effects of YBM might have a role in it by bringing about better steadiness and calming of the mind [31].

4.7. The strengths and limitations of the study

The Strength of the study was that it could show the effect of different proportions of *yogasana* and YBM practice on muscular strength, body flexibility, and balance in a *yoga* training protocol on the same participants avoiding the intergroup/participant differences to a greater extent. A very important aspect of detraining management by YBM which helps in counteracting detraining effects has been revealed.

The limitation of the study was that it could have been done on a greater number of samples and randomisation while selecting the participants could not be done.

5. Conclusion

The findings suggest that there are focused improvements of particular physical fitness components by the practice of *yogasanas* and their management by YBM. *Yogasanas* mainly help in the improvement of muscular strength, body flexibility, and balance but the YBM components have also a role in this improvement. The detraining effects of all these parameters may be managed by YBM. This is in addition to the potential role of YBM in cardio-respiratory conditioning and in faster reaction time as observed by us under the same yoga training protocol. This may have application in the physical training programs, sports, occupational health and among patients, whenever detraining takes place due to any condition like periodization of training as well as during the recuperative phase of patients with sports-related injuries or any reason when physical training involves the use of different body parts is not possible due to incapacitance.

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Author contributions

Dr Uday Sankar Ray conceptualized the study and supervised its execution. Gopinath Bhaumik Bhuian did the experiment, analysis of the data and curation. Both Gopinath Bhaumik Bhuian and Dr Uday Sankar Ray were involved in the study design, management, investigation, validation, interpretation of data, visualization and writing the manuscript.

Declaration of competing interest

The authors certify that there is no conflict of interest.

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